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THE TRANSMISSION OF LIFE THROUGH THE UNIVERSE.*

ALREADY in their earliest reflections about the nature of organic life, men must have discovered, that every living being is once generated and after a longer or shorter lifetime dies. Somewhat later, but even this in a comparatively early stage, the empirical knowledge must have been reached that organisms of one species only produce organisms of the same species, or, as we say, "the species are stable." At this period, therefore, all the different species were believed to have left the hand of the Creator in their present form. This conception still conforms perhaps with the general, so to speak, orthodox opinion.

The doctrine has often been called the "Linnæan" because Linnæus in the fifth edition of his *Genera Plantanum* strictly adheres to the same: "Species tot sunt, quot diversas formas ab initio produxit Infinitum Ens, quæ deinde formæ secundum generationis inditas leges produxere plures, at sibi semper similes, ut species nunc nobis non sint plures quam fuerunt ab initio." In the sixth edition, however, Linnæus is evolutionist, as after the words *"diversas formas"* he has added *"et constantes"* and after *"produxere plures"* has replaced the rest of the sentence by *"sibi similes quam quae fuere ab initio."* Linnæus was followed by Lamarck and Oken, but Cuvier through his authority restored the old opinion and assumed that the species known

* Translated from the Swedish by J. E. Fries.

from earlier geological epochs but now extinct had been annihilated by some of nature's revolutions, whereupon new species were produced by new acts of creation.

A great change in the general conception, however, has quickly taken place during the last decades through the widespread study of the theory of evolution, especially after Darwin developed the same in his pioneer works.

According to this theory, the species in the course of time adapt themselves to exterior conditions, and by and by the alteration becomes so great that a new species may be said to have developed from the old. Lately this theory has been amended through the work of de Vries even so far that we now say that evolution occasionally takes a leap so that an old species directly produces a new. This is called the "theory of mutation."

Therefore we now assume that every organism that we observe has descended from other widely different beings, of which we find remains and traces in geological sediments deposited millions and millions of years ago. It might accordingly be possible that every creature endowed with life to-day has developed from one extremely simple organism, but it remains to demonstrate how this one has come into existence.

The prevailing opinion is probably the one already cherished by the ancients that the lowest organisms are generated without seed. It was observed how certain low creatures, maggots, etc., grow in decaying meat, as Ovid tells us in his Bucolics. This idea obtained until the seventeenth century but was then disproved by numerous experiments conducted by scientists such as Swammerdam and Leuwenhoek. But again this theory of spontaneous generation blazed into new life after the discovery of infusoria or the small organisms which appear in decoctions and infusions apparently out of lifeless matter. Spallanzani however proved (1777) that if the infusoria as well

as the vessel and the air enclosing the same were heated sufficiently to kill all germs then the infusoria became sterile, i. e., no more life developed. The method of preparing conserves is based on this discovery. Nevertheless the argument was brought up that the heat had so transformed the air as to make it unfit for the production of life. But even this last refuge was rendered impossible when Chevreul, Pasteur and Tyndall in the years 1860-1880 demonstrated that air from which all germs had been removed even through other means than heat, for instance by filtering, became unable to develop infusoria. Especially has Pasteur, whose methods of sterilizing are in daily use in the bacteriological laboratories, forced us to conclude that germs are necessary for the production of life.

In spite thereof, prominent scientists time and again come forward with pen in hand endeavoring to prove that we must assume the possibility of spontaneous generation. In these attempts they do not employ the exact methods of natural science but rather a philosophical mode of thinking. "Life," they tell us, "must once have come into existence, and we are therefore forced to the conclusion that spontaneous generation at some specific time has taken place although it does not occur under present conditions." Much attention was aroused when the great English physiologist Huxley believed himself to have found in some silt gathered from the bottom of the deep seas an albuminous body whose origin he called *Bathybius Haeckeli* in honor of the ardent German Darwinist Haeckel. For some time it was thought that this *Bathybius* (deep-organism) constituted the "primitive slime" of organic substance, the fulfilment of Oken's dreams, from which all organisms might be considered to have originated. Closer investigations, however, by the chemist Buchanan have demonstrated that this "primitive slime" consisted only of gypsum precipitated by the presence of spirits.

Some very fantastic explanations were now resorted to. It was said, for instance, that life possibly could originate from the inner glowing mass of the earth. At a high temperature perhaps organic compounds (cyanates and their derivatives) were formed which might be possessed of life. There seems, however, to be little reason for considering these speculations, before they have at least obtained some experimental foundation.

In this connection I cannot deny myself the pleasure of pointing out that at times external conditions may have been more favorable for the production of new species than they are at present. The famous physiologist Loeb in San Francisco has shown that the hybrid of holothurian and a starfish, which cannot develop in ordinary seawater, will come to life if a certain amount of carbonic acid is added to the solution. He therefore remarked that in geological epochs, when the air was highly carbonated as during periods of marked volcanic vivacity, hybrids may have come forth in vastly greater number than now. These hybrids may possibly have propagated, and this would account for the fact that certain geological eras are conspicuous for their magnificent production of new species while others, so to speak, appear to have been comparatively sterile. But the leap from hybrid to self-generation is far too great to make the discovery by Loeb an evidence of importance in favor of the theory that self-generation might have occurred during earlier geological epochs when the external conditions differed from the present.

We must therefore take sides with the great physicist Lord Kelvin when he passes judgment on this gospel in the following words: "A very ancient speculation, still clung to by many naturalists, supposes that under meteorological conditions very different from the present, dead matter may have run together or crystallized or fermented into 'germs of life' or 'organic cells' or 'protoplasm.' But

science brings a vast mass of conducive evidence against this hypothesis of spontaneous generation, as you have heard from my predecessor in the Presidential chair. Dead matter cannot become alive without coming under influence of matter previously alive. This seems to me as sure a teaching of science as the law of gravitation."

Although this last assertion may seem somewhat exaggerated it shows how necessary some investigators have found it to look for some other explanation of the problem. We have in fact another speculation in the so-called "Panspermy," a doctrine according to which germs of life are constantly moving about throughout space, meeting the planets and filling their surface with life as soon as the conditions for organic existence are fulfilled

The origin of this idea may probably be dated long ago. Plain utterances in this direction were made (1821) by Sales-Cuyon de Montlivault in France, who assumed that germs from the moon brought into existence the first life on the surface of our earth. A German physician, Dr. H. E. Richter, offered (1865) panspermy as an amendment to Darwin's theory. Inspired by Flammarion's theory of numerous inhabited worlds, Richter asserts that seeds were brought to this earth from some other world that was in the life-bearing stage. He points out that carbon, which he holds to be of organic origin, has been found in meteorites, which, as is well known, have orbits similar to those of the comets. The organic origin of this carbon, however, is an hypothesis entirely unsupported by science, since meteoritic carbon never has shown trace of organic structure and carbon may as well be derived from inorganic matter; such for instance is found in the sun. More adventurous yet is his suggestion that organisms floating at great height in the atmosphere might be attracted by some passing meteorite and be carried out into space and transported to other celestial bodies. As a matter of fact

the surface of the meteorite is fused in its passage through the atmosphere and any germ that might possibly be attracted by it would necessarily be killed. And if, in spite of all, a meteorite should carry germ cells on its surface, these would inevitably be burned to ashes when it fell through the atmosphere of this or any other planet.

But on one point we must agree with Richter; there is perfect logic in his sentence: "The cosmic space embraces maturing, ripened and dying globes, where ripened stands for those that are ready to shelter living organisms. We therefore consider organic life in the universe to be eternal. It has existed in eternity, and has unceasingly propagated in the form of living organisms, cells or individuals composed of cells." As men formerly speculated over the origin of matter, but have given this up since experience has shown that matter is indestructible and only changes its form, and as we for analogous reasons never raise the question from where the energy of motion has come, similarly why should we not be able to familiarize ourselves with the idea that life is eternal and that therefore it is useless to search for its beginning.

The thoughts of Richter were accepted by the famous botanist Ferdinand Kohn in a popular lecture 1872. Perhaps the best-known of similar utterances is that of the great physicist Sir William Thomson, the late Lord Kelvin, who in his presidential address to the British Association in Edinburg, 1871, said:

"When two great masses come into collision in space, it is certain that a larger part of each is melted; but it seems also quite certain that in many cases a large quantity of debris must be shot forth in all directions, much of which may have suffered no greater violence than individual pieces of rock experience in a landslide or in blasting by gunpowder. Should this earth come into collision with another body comparable in dimensions to itself, at a time

when it is still clothed as at present with vegetation, many great and small fragments carrying germs and living plants and animals would undoubtedly be scattered through space. Hence and because we all confidently believe that there are at present, and have been from time immemorial, many worlds of life besides our own, we must regard it as probable in the highest degree that there are countless germ-bearing meteoric stones moving through space. If at the present instant no life existed upon this earth, it might lead to its becoming covered with vegetation. I am fully conscious of the many scientific objections which may be urged against this hypothesis, and I have already taxed your patience too severely to allow me to think of discussing any of them on the present occasion; all I can say is that I believe them all to be answerable."

Unfortunately, we cannot share in the optimism of Lord Kelvin on this point. To begin with it is doubtful if living organisms would survive the violent impact at the collision of two celestial bodies. We further know that the whole surface of a meteorite when falling upon the earth becomes heated to incandescence through friction against the air so that all adhering seeds must lose their power of germination. Plants grow almost exclusively in loose soil, and if a lump of earth were to fall through the atmosphere, it would undoubtedly, because of the resistance of the air, break into pieces each of which would become a shooting star and reach the earth only in the form of ashes. Another difficulty is that such collisions which we believe are indicated by the blazing up of new stars on the firmament are of exceedingly rare occurrence so that the chances are very small that living germs should be brought in this way to a certain spot such as our earth.

The whole theory, however, has entered into a far more favorable aspect with our growing knowledge of "radiation-force." Maxwell and Bartoli have calculated that

very small bodies of such size that they hardly become visible under our strongest microscopes are repelled by radiation, for instance, from the sun, so that this force may exceed the solar gravity. This theoretical conclusion has been verified through experiments by the Russian physicist Lebedew, and the Ameircan scientists Nichols and Hull.

The sun's radiation-force, according to calculations by the German Professor Schwarzschild, would show its influence best on bodies which if globe-shaped have a diameter of 0.16 micron. (One micron equals one thousandth part of one millimeter and is a unit frequently used in microscopy; the smallest visible particles have a diameter of about 0.2 μ.) The first question is: Do germs really exist of such infinitesimal size? To this the botanists answer that the spores of many bacteria measure 0.3μ to 0.2μ and that undoubtedly even smaller exist although we are unable to detect them under the microscope. Such no doubt cause rabies with dogs, the foot and mouth disease in cattle, and the mosaic plague on tobacco leaves, common in Indo-China and sometimes observed in Europe, and all sicknesses due to bacteria, but for which the corresponding bacilli have never been discovered, probably because of their minuteness and consequent invisibility under the microscope.

It is then most probable that living organisms exist so minute that the radiation-force of the sun would expel them out into space, where they might fecundate planets that offered them a favorable place for development. To begin with let us estimate what would happen if such a micro-organism, separated from the earth were driven out in space by the sun's radiation. Passing the orbits of Mars, the small planets, the outer planets and finally the last station in our solar system, the Neptune-orbit, it would start out in infinite space towards other solar systems. There is no difficulty in calculating the time required for

this journey by the swiftest of the small particles. Their specific weight may be considered as that of water which nearly corresponds to actuality; they will then reach the path of Mars inside of 3 weeks, that of Jupiter in 11 weeks and that of Neptune after 19 months. The nearest solar system, α Centauri, would be reached after 9000 years. (These calculations are based on the assumption that the radiation-force is four times greater than gravity at the sun, an approximate value according to Schwartzschild's calculations).

During the time required to reach any planet in our solar system, the germs of life certainly might retain their power of germination. Somewhat more disadvantageous are the conditions for the preservation of life during the passage to the nearest solar system. But we know that the suns are moving relatively to each other, so that the distance between them varies. We are able to figure out that during the course of one million years some star probably has been about five times as close to us as our nearest neighbor at present. When we estimate that life has inhabited the earth at least 100 million years, we must admit that it is of little importance if a planet should have to wait for the appearance of life a couple of millions of years after it has become ready to receive the same. In this way we reduce the time for the journey to the nearest star to 1800 years. One might doubt whether spores of bacteria or germs in general retain their latent life for such a period. It has been claimed that grains found in Egyptian sepulchres have shown capability of growth. But the sober critic has demonstrated that these statements are exceedingly questionable. Recently a French scientist, Boudin, stated that he had found spores of several kinds of bacteria in a Roman grave in Troussepoil (Vendee, France) which undoubtedly have retained their germinative power during 1800 years. This assertion, at any rate, does not seem un-

reasonable. Germs of bacteria, therefore, might possibly keep their life-bearing quality during the transportation from one planetary system to another.

On their way from our globe, the germs of life in question would be exposed to strong sunlight during about one month, and we know that the most refractable sunrays kill bacteria and their spores within a comparatively short time. As the experiments have been carried out however the spores have generally been placed on some moistened surface. (Marshall Ward's experiments.) These conditions by no means apply to spores moving in the interplanetary spaces. Furthermore, it has been shown by Roux, that the splenic fever spores, which are quickly killed by sunlight under free access of air are not affected at all in vacuum. Certain spores again suffer little if any harm from light. All the botanists that I have consulted on this point agree that there is no evidence to the end that spores traveling through space would necessarily be killed by sunlight.

It might further be argued that the spores, during by far the largest part of their journey are exposed to a cold that they might not endure. When the spores pass the orbit of Neptune, their temperature has gone down to —220° C. and still further out it is perhaps even lower. During some recent experiments at the Jenner Institute in London, spores of bacteria were kept for 20 hours at a temperature of —252° C. in liquid hydrogen gas. Their power of germination was not destroyed. Professor Macfayden in London went further still and showed that microorganisms kept for six months at a temperature of —200° C. in liquid air still would germinate. At my latest visit in London, I was told that such trials had been protracted for even longer periods with the same result.

On the contrary, it is not improbable that the power of germination will last vastly longer at temperatures lower than those common on the earth. The loss of this power

is no doubt caused by some chemical process and nearly all such actions proceed enormously slower at lower than at higher temperatures. It seems, therefore, not unlikely that the extreme cold in the interstellar space preserves, so to speak, the germs of life so as to allow a far more protracted transportation than one might judge possible from their behavior at ordinary temperatures.

We see then that the spores of the smallest earthly organisms, if once separated from our globe, would quickly be dispersed throughout the universe as seeds are scattered over a field. But now the question arises: How will they be able to leave the earth against the force of gravity? Of course such tiny and light bodies would follow the currents of air. A small particle of rain, one-fiftieth part of a millimeter in diameter falls four centimeters per second at ordinary atmospheric pressure. Hence it is easily calculated that a spore of bacteria 0.16 micron in diameter would fall only 83 meters in one year. Evidently such small particles follow the currents in the atmosphere even out into the most rarified air. By a current of two meters velocity per second they would be carried to a height where the barometer would show only 0.001 millimeter, or a height of about 100 kilometers. But by the currents in the air they could never be expelled out of the atmosphere.

In order to lift them to greater heights, we must resort to other forces and fortunately we know that electricity will help us out of almost any difficulty. On such great heights as 100 kilometers the northern lights display their resplendent radiance. We believe nowadays that the northern lights are caused by discharges from negative electricity brought with great quantities of dust from the sun. The atmosphere is there as if saturated with negative electricity. If therefore the spore in question receives a negative charge from the sundust, it might by its charged neighbor be driven out into the ether sea.

We assume now that electrical charge as well as matter is not divisible *in infinitum,* but that there exists a minimum charge which has been determined to be 5×10^{-10} electrostatic units.

It is not difficult to calculate how strong the electrical field must be that will expel such a charged spore against the force of gravity. A field of 150 volts per meter will suffice for this purpose. Fields of this strength are often, almost normally, observed at the surface of the earth in clear air. The electrical field in the region of the northern lights is in all probability much stronger, and is therefore no doubt able to expel the electrically charged spores when they are carried to this region by currents of air.

It is therefore probable that seeds of the lowest organisms we know are continually being scattered out in space from the earth and from other planets inhabited by life. But like germs in general, by far the greater portion of these will perish in the cold infinite space, a small number, however, may fall on other spheres to bestow upon them, if their conditions are favorable, the gift of life. Sometimes this may not be the case; sometimes again the seeds will meet an eager soil. And even if a few millions of years should elapse from the time when a planet is ready to receive life until the day when the first seed reaches its soil, sprouts, and takes it into possession for the use of organic life, how insignificant is this delay compared with the era during which life will blossom on the planet.

The tiny seeds expelled in this way from the homes of their parents may either travel isolated through space and, as outlined above, reach outer planets or systems of planets centered around other stars, or they might meet bigger particles rushing in towards the sun. In that part of the zodiacal light which is called in German *Gegenschein* and is regularly observed in the tropics and occasionally at our latitude in the part of the sky opposite the sun, we behold,

according to the astronomers, streams of fine dust swiftly falling into the sun as gravity commands. Suppose now that a spore 0.16 micron in diameter meets such a dust particle 1000 times greater, that is 1.6 micron in diameter, and adheres to its surface, then the spore will be carried in towards the sun, thereby crossing the orbits of the inner planets, and might fall into their atmosphere. It does not take these dust particles a long time to pass from one planetary orbit to another. Assuming their initial velocity zero at Neptune (they might then originate from one of Neptune's moons, as Neptune, Uranus, Saturn and Jupiter themselves probably as yet have not cooled off sufficiently to shelter life) they would reach Uranus's orbit in 21 and that of Mercury in 29 years. Under similar conditions, such particles would cover the distance between the orbits of Uranus and Saturn in 12 years, between Saturn and Jupiter in 4 years, between Jupiter and Mars in 2 years, between Mars and the earth in 84 days, between the earth and Venus in 40 days and between Venus and Mercury in 28 days.

It becomes evident from these figures that the dust particles with their adherent spores might fall 10 to 20 times slower without danger of the spores losing their germinating power. In other words, if the spores adhere to particles so tiny that their weight to 90 or 95% were balanced by the sun's radiation force, they might yet within a comparatively short time fall into the atmosphere of the inner planets but with a reasonable velocity, of say a few kilometers per second. It is easy to calculate that if such a particle were brought to a standstill in one second, its rise in temperature would only amount to 100° C. above that of the surrounding air because of the strong radiation. Such temperatures the spores of bacteria easily endure for even much longer periods than a second without jeopardizing their life. Once arrested the particle with its ad-

hering germ and with or without the help of aii currents would slowly sink to the surface of the new planet.

In this way life would quickly be dispersed from its home within a planetary system to other places in the same system offering favorable conditions for its existence.

Some of the germs which were not caught by such dust particles would continue their journey towards other solar systems, where they would be arrested by the radiation force from the new suns. They cannot go further than to a point where the opposing radiation pressure equals that at their starting point. Consequently germs from the earth which lies five times nearer our sun than Jupiter would approach another sun to a point five times nearer that sun than germs from Jupiter would.

In the neighborhood of the suns, where the germs stop on account of the radiation pressure and return to the inter solar spaces, there will necessarily occur a great accumulation of such seeds. The planets gravitating around these suns have better chances, then, to meet them here than if they were scattered somewhere else in space. The germs have also lost the great velocities with which they traversed the intersolar distances, and they will therefore not be heated up by falling into a planet's atmosphere to such an extent as otherwise would be the case.

In this neighborhood of the suns, we must also find a concentration of the above mentioned dust particles of a weight a little less than counter-balanced by the radiation-pressure and therefore moving towards the sun. There are comparatively good chances then that the germs here will be attracted to such particles and therefore hindered from returning to space and instead brought in towards planets nearer the suns.

In this way life may have been transplanted since eternity from solar system to solar system and from planet to planet within the same system. But as the billions of pollen

atoms that the winds will scatter in all directions from a large tree like a pine, for instance, on an average give life only to one new tree, so probably only one out of billions or perhaps trillions of germs that are dispersed from a planet by the radiation force throughout the universe, will fall on a planet not yet inhabited by life and there give birth to an infinite number of living organisms.

Finally we find according to this version of the theory of panspermy that all living beings in the universe are kindred and consist of cells built up mainly of carbon, hydrogen, oxygen and nitrogen. The fancied existence then of other worlds inhabited by beings in the organisms of which the carbon for instance is substituted by silicon or titanium seems rather dubious. Life on other inhabited worlds is probably evolving in forms very similar to those on the earth.

Further we draw the conclusion that life always has to commence from its lowest forms just as every individual, however highly developed he may be, must pass all stages of evolution, from the first simple cell.

All these conclusions harmonize beautifully with the general characteristics of life on the earth, and it cannot be denied that this form of the doctrine of panspermy possesses that degree of coherence which is the best criterion for the probability of a cosmogonic hypothesis.

There are very small chances for a demonstration of this theory through observation of the germs falling down through the atmosphere. The number of germs arriving on the earth each year, is probably extremely small. In addition, they are no doubt very similar to those of earthly origin which the winds carry in enormous quantities, and therefore, even if they should be found by scientists, their "celestial" birth would be difficult to prove.

S. ARRHENIUS.

UNIVERSITY OF STOCKHOLM, SWEDEN.